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Dispersion and Blending of SiC Whiskers in RSP Aluminum Powders

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An ultrasonic method has been developed for separating silicon carbide (SiC) whiskers in the clusters which are typically found in the as-received SiC whiskers made from rice hulls. The method has also been used to disperse the whiskers uniformly in a -325 mesh rapidly solidified (RSP) aluminum powder. Scanning electron microscopic examination of the separated whiskers and the whisker aluminum powder blend indicate that the whiskers retain a high length to diameter ratio after processing. Fully dense compacts produced by hot isostatic pressing of the blend exhibit a uniform whisker distribution.

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DISPERSION AND BLENDING OF SiC WHISKERS IN RSP ALUMINUM POWDERS

INTRODUCTION

Metal matrix composites (MMC's) of research quality are required to establish reliable relationships between material properties, composition, and processing parameters. Systematic variation of composition and consolidation parameters is necessary to determine their effect on composite mechanical and physical properties. Much of the data on silicon carbide whisker reinforced aluminum (Al/SiC_w) composites reported in the literature have been obtained on materials commercially produced using a proprietary process[1]. These commercial composites are available with a limited selection of matrix alloy and reinforcement content. Moreover, the distribution of whiskers throughout the matrix is nonuniform[2-6]. To address the problems of material availability, lack of control of material processing parameters, and nonuniform whisker distribution, a program was instituted to develop a technique for producing a uniform blend of metal powders and whiskers for subsequent consolidation and characterization.

APPROACH

Several procedures were used in the attempt to separate the individual 0.6 μm diameter silicon carbide whiskers* in the tightly packed spheroidal clusters. The preponderance of these 100- to 300- μm diameter clusters is evident in the Scanning Electron Microscope (SEM) photographs in Fig. 1. Mechanical agitation of these clusters, either dry or in various liquids, by stirring, mixing, tumbling, or ball milling did not noticeably increase the

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* Grade F-9 silicon carbide whiskers from ARCO Metals, Co., Silag Operation, Greer, S.C.

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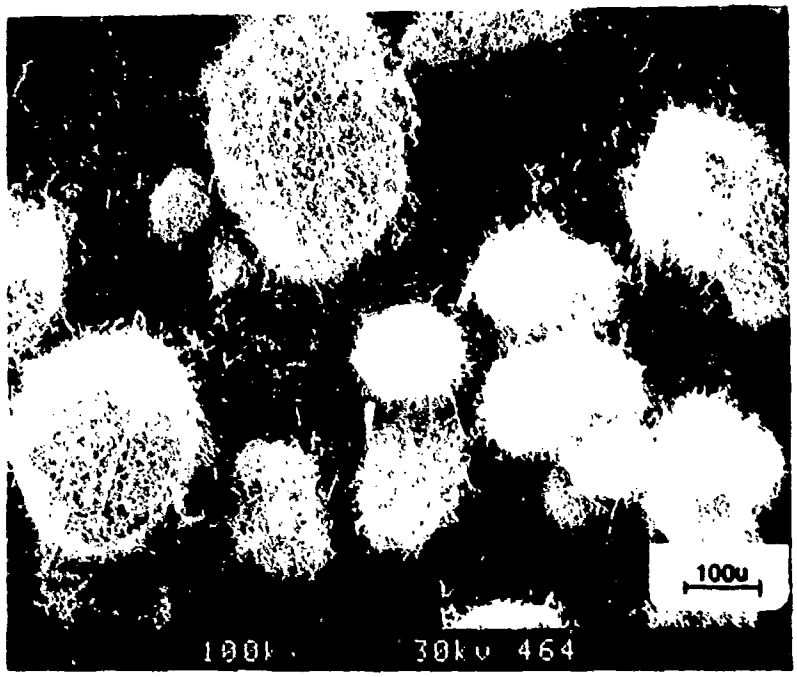
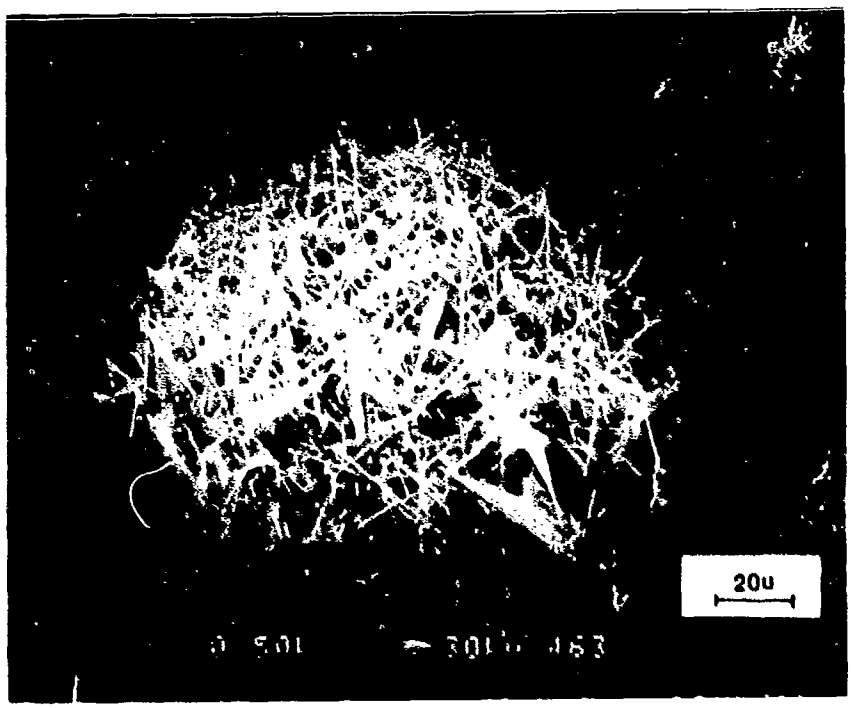


(a) 100-to 300-μm spherical clusters widely separated



(b) closely packed whiskers within a cluster

Fig. 1 - SEM micrographs of clusters in as-received grade F-9 silicon carbide whiskers

proportion of free whiskers. Low intensity ultrasonic agitation was also ineffective. Mixtures of the SiC_w and rapidly solidified (RS) aluminum powder with particle size of 44 μm and smaller were also subjected to the above procedures for up to 10 hours without significantly breaking up the clusters.

The technique that finally proved successful in separating the whiskers was the high intensity ultrasonic agitation of a cluster/isopropyl alcohol mixture. This same technique was also successful in producing a uniform blend of the whiskers and the aluminum powders.

EXPERIMENTAL PROCEDURE AND RESULTS

The whisker separation was performed as a batch process in a 500 ml Pyrex beaker Isopropyl alcohol (250 ml) and F-9 SiC_w (75 gram) were placed in the beaker and the ultrasonic disrupter** was lowered into the mixture on the axis of the beaker. Power was applied and the vertical position of the tip of the transducer was adjusted to stand 20 mm above the bottom of the beaker in order to produce vigorous, vertical circulatory motion of the mixture. After 15 minutes of agitation at 45 percent power input the power level was increased to 55 percent and the agitation continued for a total of 60 minutes.

Samples were taken at 15, 30, 45, and 60 minute intervals to monitor the progress of the cluster break-up. An eyedropper was used to extract representative samples from the mixture and to deposit drops of it on a glass slide. After the alcohol had evaporated the slides were prepared for optical and scanning electron microscopic observations.

An SEM micrograph of a typical sample of processed whiskers is shown in Fig. 2. The closely packed mats were initially thought to be collections of the original clusters. However, the material in the mat appears to be partially separated into irregularly shaped, uniform height segments which are different from the original spheroidal clusters (compare Figs. 1a and 2a). Small pieces of these mats of whiskers separated into individual whiskers when placed in alcohol and stirred. The SEM micrographs in Fig. 3 indicate the

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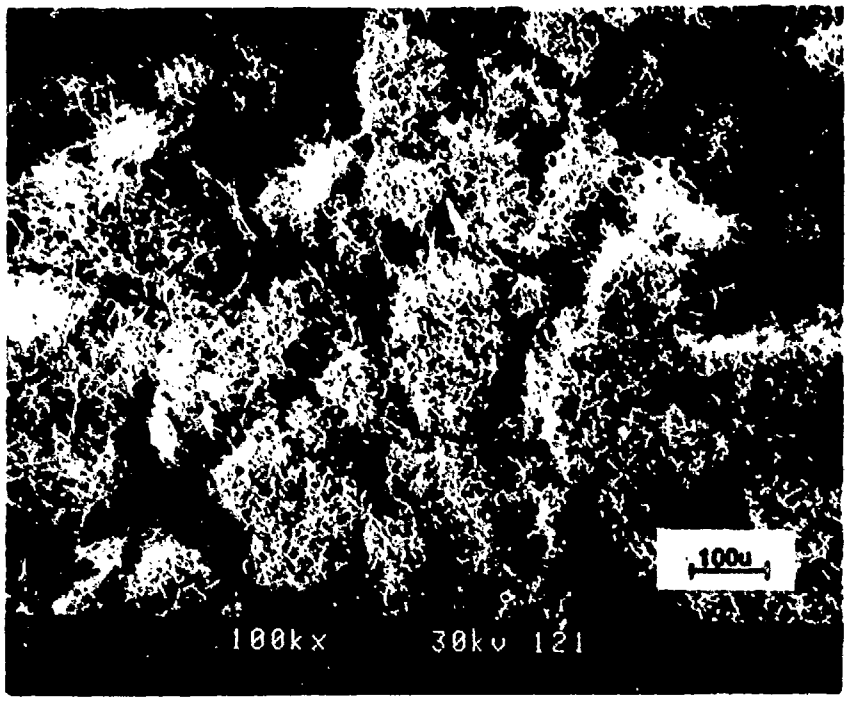
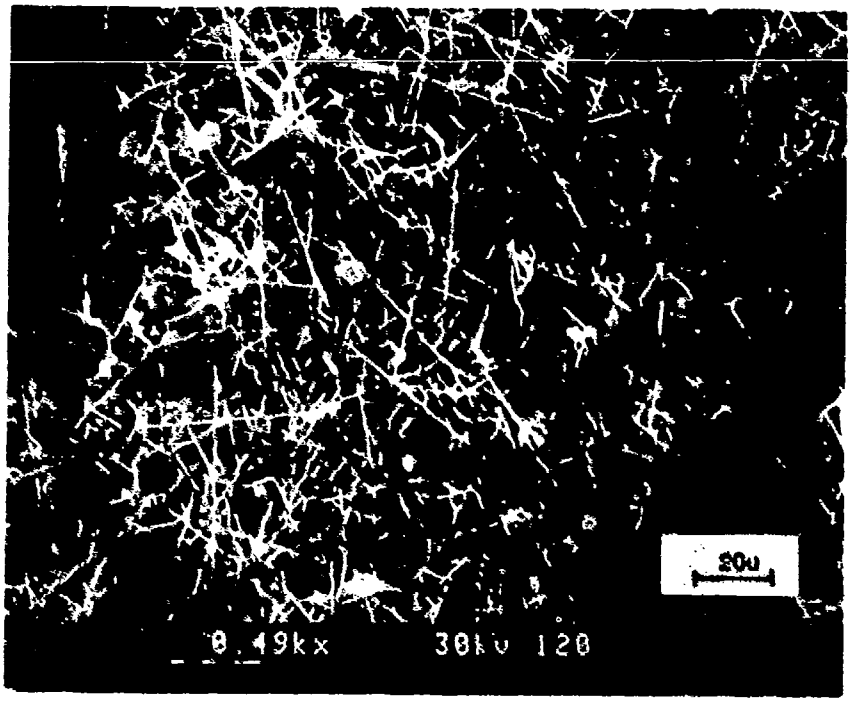
** Sonicator Cell Disrupter, Model W370 with Model C3 converter, 300 watts @ 20 khz Heat Systems - Ultrasonics, Inc., Farmingdale, NY 11735

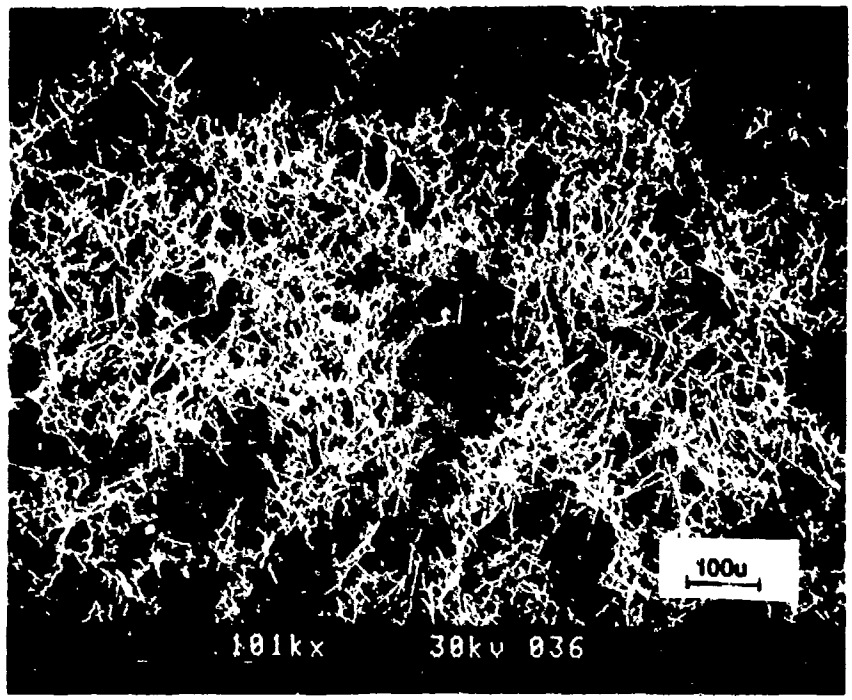


(a) closely packed clusters

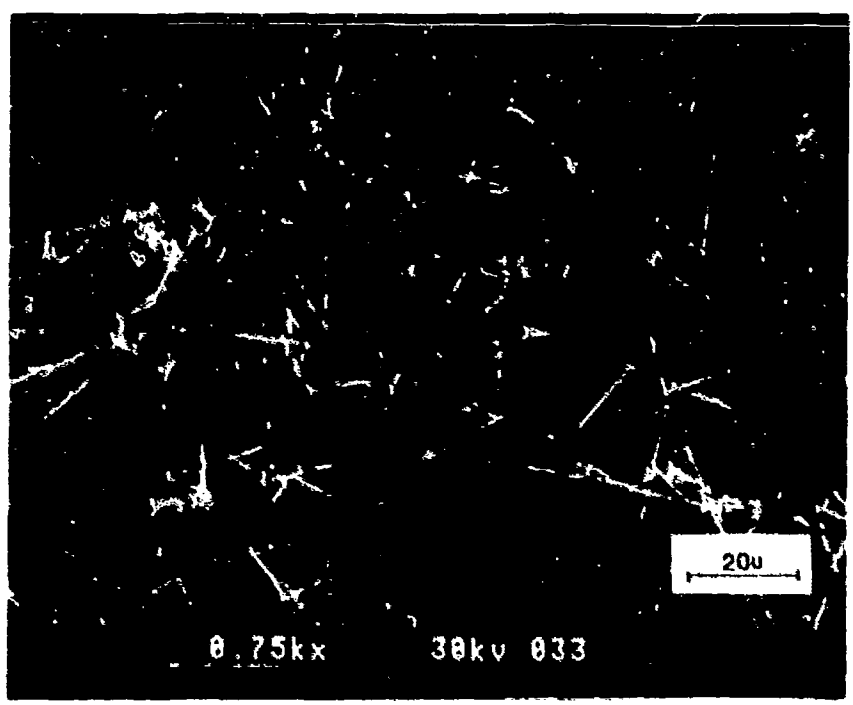


(b) loosely arranged whiskers within the clusters

Fig. 2 - SEM micrographs of dried mats of silicon carbide whiskers after ultrasonic disruption in isopropyl alcohol



(a) loosely packed mat of whiskers with no apparent cluster



(b) separated whiskers within the mat

Fig. 3 - Separated SiC whiskers after ultrasonic processing

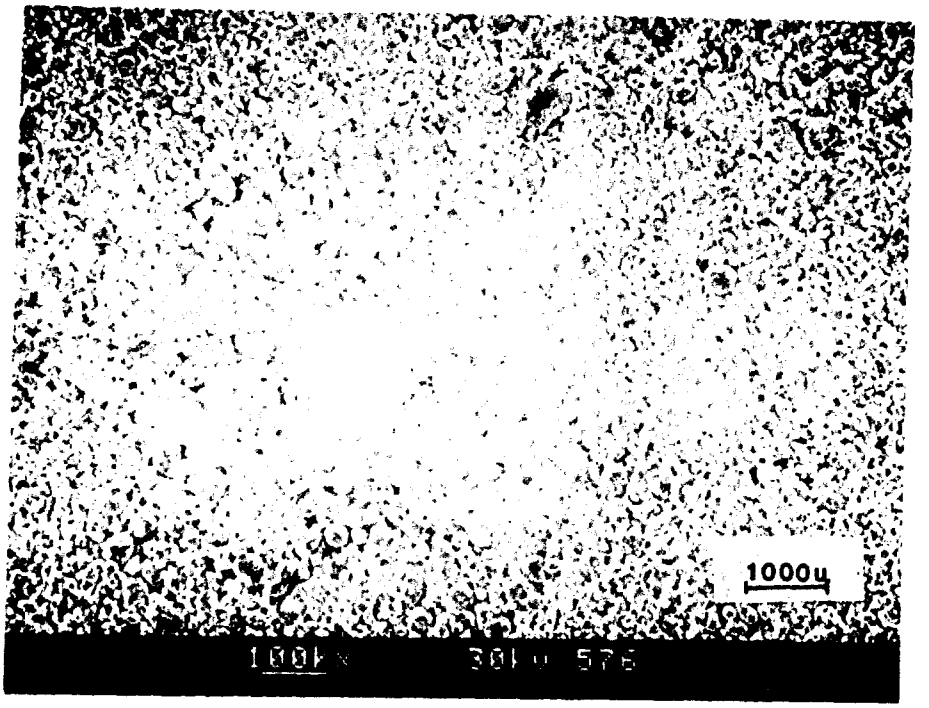
dispersed, cluster-free nature of these separated whiskers. Samples taken after 15 minutes of ultrasonic processing contained isolated clusters, but no clusters were observed in samples taken at 30, 45, and 60 minutes.

Whisker damage caused by the ultrasonic agitation was assessed by checking whisker length. In the 60-minute sample, measurement of the 60 whiskers in a test area yielded an average length of 29 μm with a standard deviation of 14.7 μm. Approximately 90 weight percent of the whiskers were 20 to 60 μm long. Whisker lengths could not be determined on the as-received material because of the presence of clusters. However, the manufacturer reports[1] that 80 weight percent of as-produced whiskers are 20 to 60 μm in length. The difference between as-produced and processed whisker lengths is attributed to sampling and is not considered significant.

After 60 minutes of ultrasonic processing, the whiskers were allowed to settle to the bottom of the beaker. The isopropyl alcohol was decanted off, and the whiskers were dried in an oven at 175 °F for 24 hours. The resultant cake of whiskers disintegrated easily and portions of the cake which were remixed with alcohol again separated into individual whiskers without apparent reclustering. However, dry mixing of these whiskers with -325 mesh RSP aluminum powder in either a ball mill or a twin-shell blender produced reclustering of the whiskers and poor whisker distribution throughout the aluminum powder.

The simultaneous separation of the whiskers from the clusters and blending with an RSP aluminum powder was accomplished using the same ultrasonic procedure as above. Ultrasonic processing at 55 percent power for 13 minutes completely dispersed 25 volume percent of F-9 silicon carbide whiskers uniformly and randomly throughout a -325 mesh Al-8Fe-4Ce RSP powder. A sample of the dried blend is shown in Fig. 4 which indicates that the mixing of powder particles and whiskers is uniform.

The dried blend was transferred to a cylindrical aluminum can, degassed, and consolidated below the alloy solidus temperature by hot isostatic pressing. The resultant composite was sectioned, polished, and etched for metallographic examination. The whiskers appeared to be uniformly and randomly distributed along the powder particle boundaries. A deeply-etched specimen showing such a distribution is shown in Fig. 5.



(a) Both powder particles and whiskers uniformly distributed on a macro-scale

(b) Whiskers intimately mixed and randomly oriented around powder particles on a micro-scale

Fig. 4 - Uniform dispersion of SiC whiskers in an aluminum powder after ultrasonic disruption

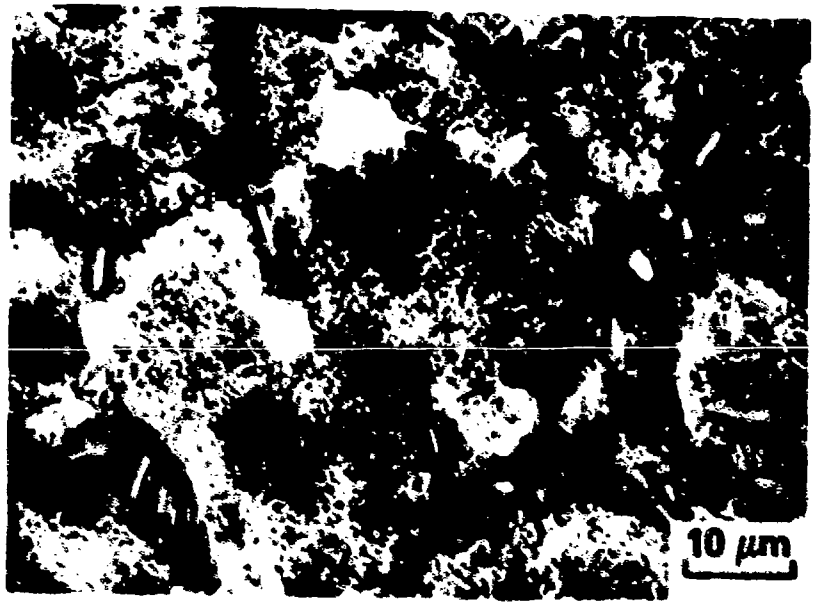


Fig. 5 - Silicon carbide whiskers randomly distributed at powder particle boundaries in an RSP Al/SiC_w composite

SUMMARY

A process has been developed which efficiently disrupts the silicon carbide whisker clusters with minimal reduction in whisker length. The same technique has been used to separate the whiskers and distribute them uniformly throughout a -325 mesh aluminum powder. Consolidaton of the resultant Al/SiC_w blend by hot isostatic pressing produced a composite with 25 volume percent silicon carbide whisker uniformly distributed and randomly oriented throughout the material.

The technique is amenable to multiple batch processing or, with slight modifications, to continuous operation by providing a means for the constituents to flow through the apparatus with a suitable dwell time in the high intensity ultrasonic field.

Composite materials prepared using this technique can be custom designed with a desired matrix alloy and whisker content. The properties of the composites should exhibit greater uniformity and be closer to theoretical values since the randomly oriented whiskers are uniformly distributed both on a macro- and micro-scale. This should expedite the characterization of silicon carbide whisker reinforced composites.

ACKNOWLEDGMENT

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